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METHYL BROMIDE FUMIGATION OF COTTONSEED IN FREIGHT CARS FOR THE DESTRUCTION OF PINK BOLLWORMS[1/]

By G. L. Phillips,
Division of Stored Product Insect Investigations

From 1945 to 1951 experiments were carried on in Texas to determine how methyl bromide fumigation could be utilized in the treatment of cottonseed originating in areas quarantined because of the pink bollworm, to prevent it from being disseminated through transportation. Heat treatment had long been the standard practice, but in many instances fumigation would be much easier.

Preliminary tests demonstrated that pink bollworm larvae embedded in cottonseed were killed by exposure to moderate concentrations of methyl bromide. In 1946 methyl bromide fumigation of sacked cottonseed intended for planting purposes was approved for use under the pink bollworm quarantine (BEPQ 558). In a revision of this quarantine in 1948 methyl bromide fumigation of bulk cottonseed in large steel storage tanks was approved for use. A forced circulation system was provided to distribute the gas through the seed mass (Phillips and Bodenstein 1). The development of a method for fumigating bulk cottonseed in freight cars or trailer vans is described herein.

Tests on freight-car fumigation were carried on at El Paso from 1945 to 1949. During 1949 and 1950 further tests were made near San Antonio. The first commercial evaluation tests were made at Lubbock.

All tests were made with carload lots of bulk cottonseed. In the El Paso area no cottonseed was moved commercially by railway freight; so it was necessary to load freight cars especially for the tests, and then remove the seed before another loading. Cottonseed and unloading

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1/ The following members of the Bureau assisted: J. K. Blocker, A. L. Broman, J. S. Cook, Roy A. Fischer, A. H. Halverson, G. G. Harris, P. L. Netterville, R. R. Rost, and R. S. Van Hoak. The following members of the Texas Department of Agriculture also assisted: C. W. Foster, G. C. Harris, and Edgar Jung. Acknowledgement is also due to L. F. Curl, director of the Southwestern Region of the Bureau, for his constant support of the research program.

facilities were kindly provided by the Farmers Cooperative Oil Mill at El Paso. Tests near San Antonio were performed in carloads of seed provided by the Swift and Company Oil Mill.

Because of the large amount of labor needed for loading and unloading cars, locating samples, and cutting thousands of individual cotton seeds to determine mortality (samples averaged from 13 to 60 larvae per 1,000 seeds), only a few carloads could be tested in one season.

Tests without Forced Circulation

Before the value of forced circulation was demonstrated by fumigation in steel storage tanks, various methods were used to apply methyl bromide in efforts to attain satisfactory distribution throughout the load of cottonseed. They included (1) introduction of the entire methyl bromide dosage in the head space above the load; (2) injection of the entire dosage into the load; (3) introduction of half above the head and injection of the other half; and (4) application as a spray (dissolved in carbon tetrachloride) to the surface of the load. Innovations were tried, such as partial loads, additional sealing of floors and doorways with gas-proof material, circulation of the gas above the load, providing risers (vertical tunnels) through the load to assist penetration of dosage applied with a blast of carbon dioxide, and liberation of the dosage into tunnels through the load.

In most tests 1/2-pound samples of infested cottonseed were placed at selected locations throughout the seed mass. In some tests 30 of these samples were used, in others 24, and in a few 15. Each sample contained from 1,200 to 1,500 seeds and from 25 to 100 larvae. In 1948 a procedure for drawing and analyzing gas samples was put into use. Thereafter both seed and gas samples were taken to determine distribution.

The results are summarized in table 1. In only two tests was complete mortality attained in all samples, and repeated tests with the same procedure gave different results.

At first the data were interpreted to mean that freight cars were too leaky to serve as good fumigation chambers. After the better methods of sealing cars had been developed, it became evident that faulty distribution of the gas was the reason for areas of low concentration.

Table 1.--Summary of attempts to obtain satisfactory distribution of methyl bromide gas through carload lots of cottonseed. Exposure time 20 hours unless indicated otherwise.

Method and dosage (pounds per 1,000 cu. ft.)	Temperature	Conditions of tests	Samples with complete mortality
	°F.		Percent
Volatilized in air above load			
3	85-76	Full load	53
2.5	77-83	do.	66
2	78-83	do.	63
6	74-73	do.	60
	47-50	2/3 load 6 ft. deep	100
	67-69	Full load[1/]	80
	58-62	3/4 load 7 1/2 ft. deep	33
	68-60	2/3 load 6 ft. deep	53
	74-78	do.[2/]	47
	68-70	2/3 load 6 ft. deep	60
	60-70	Full load	83
	78	Full load, floors covered, doors double-sealed	83
	65	2/3 load, floors covered doors double-sealed	93
	70-82	Full load, circulation above load 30 min., floors covered, doors double-sealed	66
	76-72	Full load, risers in load, floor covered	100
		Full load	[3/]
		Full load, risers at center each end of car	[3/]

1/ Exposed 48 hours.
2/ Exposed 45 hours.
3/ No samples, gas analysis indicated unsatisfactory distribution.

Table 1.--Continued

Method and dosage (pounds per 1,000 cu. ft.)	Temperature	Conditions of tests	Samples with complete mortality
	°F.		Percent
Sprayed on top of load			
In 1.25 gal. of carbon tetrachloride			
2.5	87-89	Full load, spray applied from 40-ft. boom down center of ceiling	33
	83-93	do.	33
1.5	80-82	do.	17
5	79	3/4 load, spray applied as above	75
	67-70	Full load, spray applied from traveling boom	40
In 2 gal. of carbon tetrachloride			
6	78-79	Full load, floors covered, doors double-sealed, spray applied from traveling boom	90
		2/3 load 6 ft. deep, rest same as above	90
Injected into load 6 in. below surface			
6	75-71	Full load, dosage injected from 40-ft. boom, floor covered, doors double-sealed	50
	68	Full load, dosage injected from buried boom	57
Dosage split, half injected at 6-in. level, half released in air space above load			
8	68	Full load, half of dosage injected from buried boom	97

Table 1.--Continued

Method and dosage (pounds per 1,000 cu. ft.)	Temperature	Conditions of tests	Samples with complete mortality
	°F.		Percent
Dosage split, two-thirds released in tunnels in load and one-third in air space above			
6	-	Full load, two tunnels formed at 5-ft. level at center of each end of car	92
Injected into load followed by blast of carbon dioxide			
6	-	Full load, portion of dosage injected at 4, 12, and 20 ft. from each end of car	4/
		do.	62
		do.	66

4/ No cottonseed samples included, gas analysis indicated unsatisfactory distribution.

Tests with Forced Circulation

The satisfactory distribution of methyl bromide in large steel storage tanks resulting from forced circulation prompted attempts to utilize forced circulation in freight-car fumigation. The arrangement in the steel tanks permitted a fairly even flow of air, or gas, through the cottonseed from top to bottom, because of a reduction in pressure beneath the load as air was withdrawn from beneath the false floor, and an addition of pressure above the load as the air was returned to the head space under considerable velocity. Since it was not feasible to place a raised floor in the freight car and thus permit an even reduction over the entire floor area, air was removed from one portion of this area by means of ducts laid on the car floor.

In the exploratory tests a blower was placed on top of the load of cottonseed to suck air from the floor level through perforated hose buried beneath the load. This arrangement gave fairly satisfactory distribution, for all pink bollworm larvae were killed in the 24 samples of cottonseed in each of the last two tests. The gas samples withdrawn in two successful tests, in which the load was treated with 6 and 8 pounds of methyl bromide per 1,000 cubic feet, showed the following concentrations, in ounces per 1,000 cubic feet:

Time	6 pounds	8 pounds
30 minutes	88 - 12	116 - 7
3 hours	50 - 12	68 - 15
6	33 - 13	56 - 19
10	33 - 16	40 - 16
24	17	24 - 16

These tests show that, even though complete mortality was obtained in all the samples of cottonseed, there was considerable variation in gas concentration at the 24 selected points. The points of low concentration were not associated with any position in the car, although they occurred more often at the floor level than in the body of the load. Further tests with improved circulation were therefore undertaken.

Additional tests were made in an experimental fumigation chamber to determine the minimum lethal concentration. The results of these tests are given in table 2.

Table 2.--Mortality of pink bollworms fumigated for various periods with gas concentrations comparable to the low point in freight-car tests. Fumigations made in a 50-cubic-foot chamber at temperatures above 70^0 F.

30 minutes	3 hours		6 hours		10 hours		24 hours	
Ounces per 1,000 cu. ft.	Ounces per 1,000 cu. ft.	Percent mortality	Ounces per 1,000 cu. ft.	Percent mortality	Ounces per 1,000 cu. ft.	Percent mortality	Ounces per 1,000 cu. ft.	Percent mortality
14	13	72	12	86	10	100	7	100
14	12	70	11	85	10	96	8	100
14	13	67	12	80	10	94	8	100
16	16	80	16	96	13	-	12	100
8	9	66	8	80	9	100	7	100
15	14	72	14	91	15	100	12	100
16	16	75	15	93	15	100	12	100
17	16	75	14	88	14	100	12	100
17	17	77	15	92	15	100	14	100
18	17	67	16	83	15	100	11	100
18	16	69	15	92	14	100	12	100

From these tests it was concluded that complete mortality of pink bollworm larvae could be expected if the concentration could be kept above 10 ounces per 1,000 cubic feet at all points in a carload of seed for the first 10 hours.

A better circulation system was devised which utilized a portable blower operated outside the car. A 4-inch duct made of downspouting and perforated with 1/4-inch holes on three sides at 2-inch intervals, but with the distal end closed, was laid down the center of the car floor from end to end before it was loaded (fig. 1). A 6-inch side duct led from the center to one doorway. This doorway, opposite the loading door, was sealed off with a paper grain door[2/] properly lapped and sealed gastight, and the side duct was inserted through the paper seal (fig. 2). The ducts were then covered by the load of seed. A portable blower (fig. 3) with a gastight bearing was attached by 6-inch flexible tubing to the duct protruding through the paper seal (fig. 4). The discharge of the blower was returned to the head space above the load by another length of flexible tubing attached to a metal collar inserted at the top of the paper seal. A blower driven by a 2-horsepower motor was used. The fumigant was applied as a gas in the discharge duct of the blower where it was carried to the head space above the load and drawn down through the seed.

A series of six tests were made with this circulation system, with a dosage schedule of 6 pounds per 1,000 cubic feet for 24 hours. The blower was operated for only about 10 minutes after the fumigant was applied. The ranges of concentration obtained are shown in table 3. Even though the concentration at certain sampling points dropped below 10 ounces at the 10-hour period, it was far above that amount after 3 hours. The fact that these concentrations were above the minimum lethal amount was substantiated by the fact that all larvae in the cottonseed samples were killed.

Table 3.--Range of concentration of methyl bromide after forced-circulation fumigation of freight carloads of cottonseed.

Number of samples	Ounces per 1,000 cubic feet after--			
	30 minutes	3 hours	10 hours	24 hours
21	16 - 43	14 - 39	7 - 21	4 - 9
22	27 - 116	15 - 112	8 - 33	6 - 14
22	20 - 114	18 - 116	7 - 24	6 - 11
21	37 - 84	16 - 35	11 - 27	9 - 16
22	53 - 93	30 - 53	14 - 27	7 - 26
21	17 - 110	16 - 69	8 - 21	6 - 13

2/ The use of the paper grain door was suggested by J. K. Blocker and W. F. Sennette, Division of Pink Bollworm Control.

Application of Treatment for Quarantine Purposes

On the basis of these tests, fumigation of cottonseed in freight cars, using a forced-circulation system similar to that used in the experiment, was authorized for quarantine purposes in February 1950. As a safety factor the dosage was set at 7 pounds per 1,000 cubic feet when the bulk-cottonseed temperature averaged 60° F. or above. Use of the method was limited to certain regulated areas with very light infestation where adequate heat-treatment equipment was not available. By arrangement any commercial use was to be supervised by the writer for the first season, in order that improvements desirable for operation under practical conditions might be introduced.

The Southland Cotton Oil Company used this method on approximately 12,000 tons of cottonseed to be shipped by rail from Lubbock, Tex. A total of 306 cars were fumigated in this operation.

The same fumigation procedure was used for all cars. Only steel freight cars in good condition were used, each one being inspected and approved. Before being loaded, the floor of each car was covered with sisal-kraft paper, which is gasproof, and the perforated floor duct was put in place. The rear doorway (opposite the loading door) was sealed with a paper grain door, and collars were inserted for the attachment of the flexible tubing leading to and from the portable blower. Wooden grain doors were placed in the loading door to the height of the load. The seed was transferred from a trackside warehouse or from trucks by a seed pump (fig. 5), in which the cottonseed is sucked up by a powerful blower and blown through ducts into the car. The top of the load was leveled off to give at least a 2-foot head space.

When the loading was completed, the loading door was sealed in part with a paste made of asbestos cement and oil and in part with scotch masking tape. The flexible blower ducts were attached to the collars in the paper grain door. The blower, which was driven by a 5-horsepower gasoline engine, was started, and the dosage of methyl bromide admitted to the exhaust duct after being volatilized by passing through a coil immersed in very hot water. The blower was operated for approximately 2 minutes after the gas was introduced and then detached. The collars in the paper grain door were removed and the holes quickly sealed with gasproof paper and masking tape. The car door was then closed and the fumigation allowed to proceed for 24 hours without further attention. The blower unit was moved to the next car to be fumigated.

As many as 16 cars were fumigated in one day, the limiting factor being the speed of loading. One portable blower unit was considered capable of handling 20 cars per day.

The actual fumigation procedure was handled by representatives of the oil-mill company.[3] The certification of the cottonseed was handled by regular inspectors of the Bureau of Entomology and Plant Quarantine.[4]

The method developed for testing the efficiency of gas distribution in large steel tanks, whereby two gas samples were withdrawn from a selected sampling point at any time during the fumigation period, and the results of analysis compared with a standard curve (Phillips and Latta 2), was adopted as a means of observing the effectiveness of the freight-car fumigation at Lubbock.

The lowest concentration of gas was found to be at a point near the floor about half way between the car wall and the center duct and about one-third the distance from the end wall to the doorway. This was designated as the standard sampling point. A curve was plotted based on the average of the concentrations present at this point in tests. The lowest concentration present at this position in the experimental cars which was associated with complete mortality in biological samples was considered as the maximum deviation from the average.

A sample was withdrawn from a car under fumigation by inserting a sampling probe through the paper grain door near the floor level along a line between the center of the doorway and one of the opposite corners. By inserting the probe 14-1/2 feet at this angle the standard sampling point was reached consistently with accuracy. The analysis of this sample was matched against the curve to indicate the efficiency of distribution in each car sampled.

It was not possible to sample all cars fumigated, but an attempt was made to sample at least half of those fumigated each day. Analyses were made on samples from 162 of the 306 cars fumigated, and only one fell below the maximum allowable deviation. This car was re-fumigated.

The samples were withdrawn when convenient, so that the time of sampling ranged from 30 minutes to 17 hours after the start of the exposure. These concentrations at the sampling points were grouped according to 1-hour intervals, i.e., those between 0.5 and 1.4 hours, 1.5 and 2.4 hours, etc., and an average was taken for each interval. These data were compared with the concentrations found in the seed mass in large steel tanks under fumigation and with the concentration found at the standard sampling point in the experimental fumigations as shown in figure 6.

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[3] J. R. Richardson and Frank P. Dickson.

[4] Certification was supervised by H. L. Alford, M. E. Currie, and G. W. Chowns, and performed by Inspectors T. P. Patterson, R. J. Morits, E. L. Wilde, E. I. Fosmire, R. K. Robinson, A. S. Pela, and Ike Laird of the Division of Pink Bollworm Control. They also assisted the research staff in many ways as their duties permitted.

The fumigation of 306 carloads of cottonseed with only one rejection and the satisfactory concentration patterns found in the sampled cars were considered ample proof of the practicability of freight-car fumigation with the apparatus developed for forced circulation. Therefore, in July 1950, the quarantine regulations in BEPQ 558 were further modified to authorize freight-car fumigation in lieu of heat treatment in all lightly infested areas in Texas, New Mexico, and Oklahoma, and as an additional treatment for cottonseed moving from heavily infested areas.

Summary

Methyl bromide fumigation was authorized for the treatment of sacked cottonseed in 1946, and for bulk cottonseed in large steel storage tanks fitted with means for forced circulation in 1948. A method for fumigating bulk cottonseed in freight cars, developed between 1945 and 1951, is described in this paper.

Efforts were made to attain a satisfactory distribution of methyl bromide throughout a freight-car load of cottonseed by various methods of application, such as applying it in the head space above the load, injecting it into the load, applying half the dosage above and injecting half, and dissolving in carbon tetrachloride and spraying on the surface. None were successful. Other innovations, such as partial loads, additional sealing of floors and doorways with gas proof material, providing risers (vertical and horizontal tunnels) through the load to assist in penetration, and following the application with a blast of carbon dioxide, were also unsuccessful.

Attempts were then made to adapt the method of forced circulation used in fumigation of cottonseed in large steel storage tanks. A gas-distribution pattern was obtained that provided a lethal concentration at all sampling points. In the method finally adopted a portable blower operated outside the freight car pulls air from beneath the load through a specially designed duct system and returns it to the space above the load. The blower is run during gas volatilization and for 2 to 10 minutes thereafter, then disconnected, the car sealed, and the blower moved to the next car to be fumigated.

This method for treating cottonseed was authorized for use on quarantined cottonseed in February 1950 in a limited area under supervision. The dosage schedule is 7 pounds per 1,000 cubic feet for 24 hours exposure at 60° F. or above, and 8 pounds at lower temperatures.

The first trial on a commercial basis was at Lubbock, Tex., where approximately 12,000 tons of cottonseed in 306 freight cars were fumigated. All but one of the 162 cars that were checked by gas analyses were found to have the required gas concentration.

In July 1950 the forced-circulation method was authorized as an alternate method for treating cottonseed for the destruction of pink bollworm larvae.

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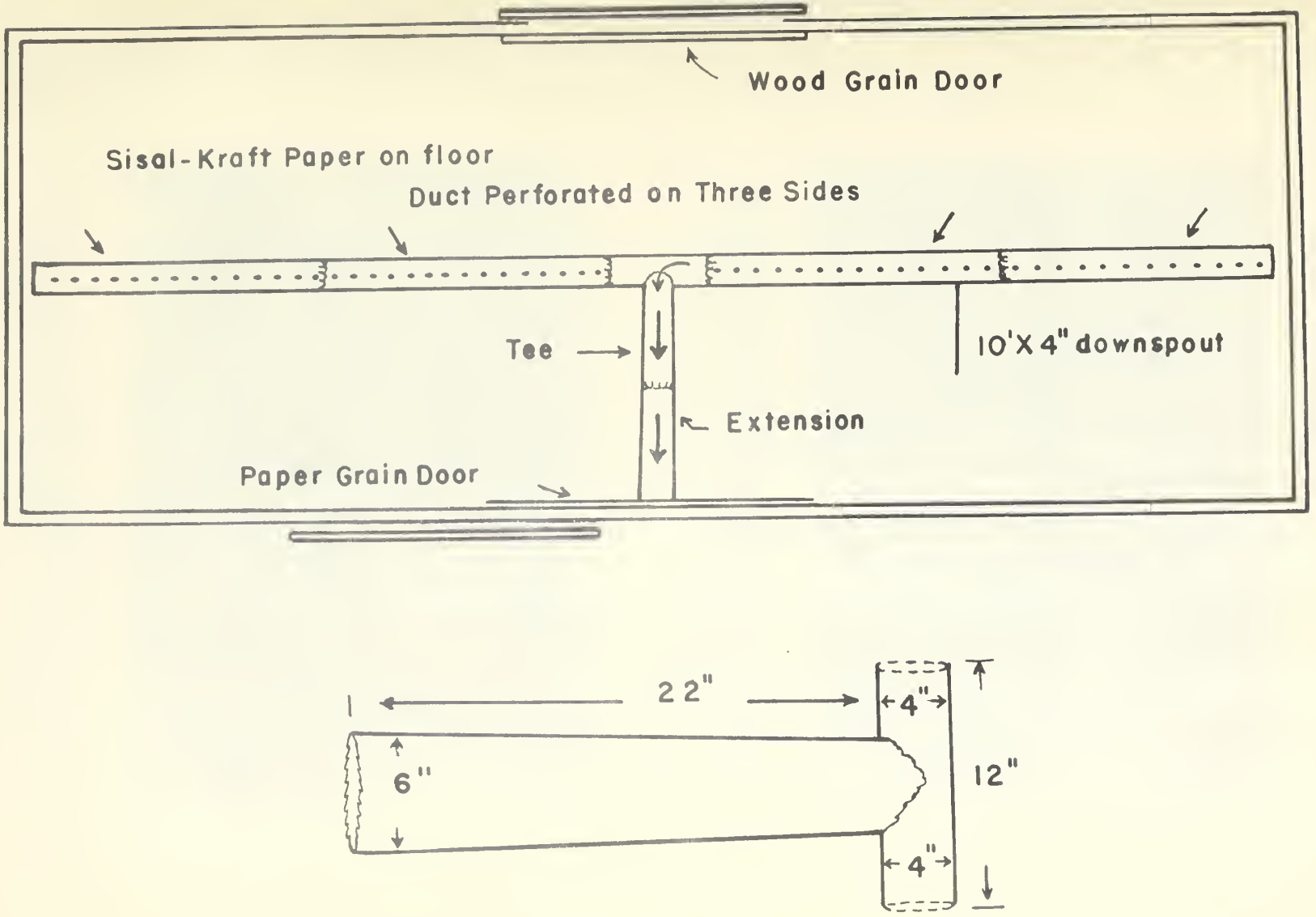

Figure 1. --Diagram showing the placement of the ducts on the floor of the car, and the construction of the tee and side extension.

Figure 2. --Car loaded ready for fumigation, showing collars inserted at top and bottom of grain door.

Figure 3. --Gasoline engine mounted to drive circulating blower. The volatilizer unit and the scales for weighing dosage are also shown.

Figure 4.--Volatilizer and circulating unit attached to one of several loaded cars ready for fumigation. The unit could handle one car in 15 to 18 minutes.

Figure 5.--Portable seed blower transferring cottonseed from a truck to a freight car.

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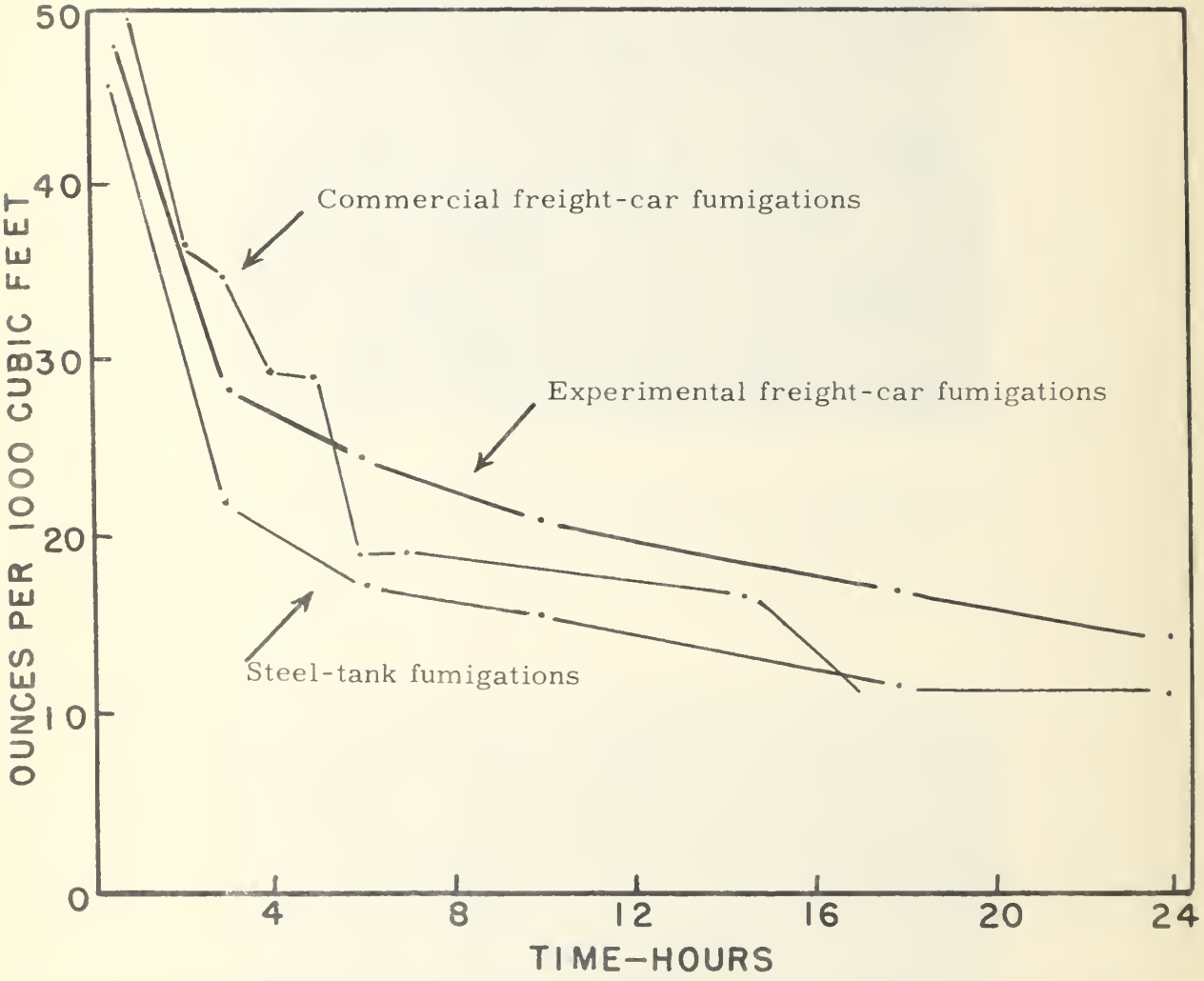

Figure 6.--Methyl bromide concentrations at standard sampling points in commercial and experimental freight-car fumigations as compared with steel-tank fumigations.